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SCREENING STUDY FOR BACKGROUND INFORMATION AND SIGNIFICANT EMISSIONS FOR GYPSUM PRODUCT MANUFACTURING

PROCESSES RESEARCH, INC.

PREPARED FOR

ENVIRONMENTAL PROTECTION AGENCY

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INDUSTRIAL PLANNING AND RESEARCH

SCREENING STUDY FOR BACKGROUND INFORMATION AND SIGNIFICANT EMISSIONS FROM GYPSUM PRODUCT MANUFACTURING

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Prepared for

Control Systems Division

Environmental Protection Agency

Submitted by

PROCESSES RESEARCH, INC.
Industrial Planning and Research
Cincinnati, Ohio

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INDUSTRIAL PLANNING AND RESEARCH

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ABSTRACT

The report deals with the atmospheric emissions that are produced during the operation of calcining gypsum and production of gypsum board products. The average particulate emissions from these plants are between 25 and 40 pounds per hour with baghouse collectors and electrostatic precipitators generally being employed as control devices. Extrapolation of emissions from all plants indicate that total emissions are in the range of 80,000 tons per year. Emission of sulfur oxides is primarily dependent upon the sulfur content of the fuels being used for calcining and other operations, and production of nitrogen oxides is also a function of the combustion equipment and fuels used. Emission regulations relating to visible, particulate, sulfur oxide, and nitrogen oxide emissions are shown for nine states A description of a general process for production of calcined gypsum and gypsum board products is given with flow diagrams. A list of gypsum and/or gypsum product producers is shown along with total industry production capacity, best controlled plants and their control equipment, and emissions data from various production locations. A brief description of emission analysis, applicable control technology, and economics of control equipment is included.

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SECTION I - PURPOSE AND SCOPE

This report provides the Control Systems Division, Environmental Protection Agency, with preliminary qualitative and quantitative data related to the operation of plants for the production of gypsum and gypsum products.

The general purposes of this preliminary study were to identify sources of atmospheric emissions in this industry, to identify and quantify such emissions and to evaluate the state of the art in terms of equipment currently employed for the control of such emissions.

The scope of this preliminary report deals with the two major industry operations:

A. Calcining of gypsum.

B. Production of board products.

SECTION II - SUMMARY

Review of the emissions data contained in this report will disclose that the "best controlled" gypsum calcining plants and board plants employ bag collectors and/or electrostatic precipitators. The average particulate emissions for these plants are in the range of 25 to 40 pounds per hour and these plants will generally comply with existing air pollution regulations.

If all plants were so equipped, the total nationwide emissions of particulates would be on the order of 12,000 tons per year.

Extrapolation of the data for all plants indicates that total emissions of particulates to atmosphere are in the range of 80,000 tons per year.

SECTION III - AIR POLLUTION REGULATIONS

Gypsum product plants are located in 28 states. Ten of these states have been selected as representing a cross section of the areas in which these plants are located.

A summary of the pertinent regulations of each of these states (with the exception of California) is given below. In California, each county has its own regulations and a county by county analysis of these regulations is not deemed to be appropriate for this report.

The 10 states involved are:

California	Michigan
Florida	New Jersey
Georgia	New York
Indiana	Oklahoma
Iowa	Texas

The regulations abstracted deal with:

1. Particulate Emissions from Process Sources.
2. Visible Emissions.
3. Emission of Nitrogen Oxides and Sulfur Oxides from Fuel Burning Operations.

1. PARTICULATE EMISSIONS FROM PROCESS SOURCES

The allowable emission, in pounds per hour, is based on the process weight rate. Process weight is defined as the total weight of all materials introduced into any source operation. Solid fuels charged are considered as part of the process weight, but liquid and gaseous fuels and combustion air are not. The rate of allowable emission is shown in Table I.

TABLE I

REGULATIONS APPLICABLE TO GENERAL PROCESS SOURCES

RATE OF ALLOWABLE EMISSION, LBS PARTICULATE/HR

	Process Weight Rate, Lbs/Hr											
	100	1,000	5,000	10,000	20,000	40,000	60,000	120,000	200,000	1,000,000	2,000,000	6,000,000
Florida	.55	2.25	6.34	9.73	14.99	23.0	29.60	33.28	36.11	46.72	--	--
Georgia[1]	.551	2.58	7.58	12.0	19.2	30.5	40.0	46.3	51.2	69.0	77.6	92.7
Indiana	.551	2.58	7.58	12.0	19.2	30.5	40.0	46.3	51.2	69.0	77.6	92.7
Iowa	.55	2.58	7.58	12.0	19.2	30.5	40.0	46.3	51.2	69.0	77.6	92.7
Michigan	.55	2.58	7.58	12.0	19.2	30.5	40.0	46.3	51.2	69.0	77.6	92.7
New Jersey[2]												
New York[3]	.50	2.3	6.7	10.8	17.4	27.6	36.1	51.8	56.1	71.7	78.3	90.24
Oklahoma	.551	2.58	7.58	12.0	19.2	30.5	40.0	46.3	51.2	69.0	77.6	92.7
Texas	--	1.6	7.7	15.2	30.1	59.7	67.4	82.3	95.2	151.2	184.4	252.3

Notes for Table I

1. For new equipment only. For existing equipment the values are the same through 60,000 pounds per hour. For over 60,000 pounds per hour, the values are:

Process Weight Rate Lbs/Hr	Allowable Emissions Lbs/Hr
120,000	63.5
200,000	89.7
1,000,000	262.0
2,000,000	414.0
6,000,000	873.0

2. New Jersey does not follow this format. Their format is:

Potential Emission Rate from Source Operation Lbs/Hr	Allowable[a] Emission Rate Lbs/Hr	Source Gas Emitted From Source Operations Scfm	Allowable[b] Emission Rate Lbs/Hr
50 or less	0.5	3,000 or less	0.5
100	1.0	6,000	1.0
1,000	10.0	35,000	6.0
2,000	20.0	70,000	12.0
3,000 or more	30.0	140,000	24.0
		175,000 or more	30.0

a. Based on 99 percent collection efficiency.
b. Based on 0.02 grains per scf.

3. Applies to sources with an environmental rating of B or C. Allowable emission rate from sources with an A or D rating is at the discretion of the Department of Environmental Conservation.

2. VISIBLE EMISSIONS

a. Process Sources

These emissions are graded on the basis of equivalent opacity which is the degree to which an emission, other than gray or black smoke, is partially or wholly impervious to rays of light and causes obstruction of an observer's view. This is expressed as an equivalent of the obstruction caused by a gray or black smoke emission of a given density as measured by a Ringelmann Smoke Chart.

b. Fuel Burning Operations

Opacity is determined by use of a Ringelmann Smoke Chart.

The Ringelmann Smoke Chart is published in the U. S. Bureau of Mines Information Circular No. 8333.

The allowable opacities are shown in Table II.

TABLE II

REGULATIONS APPLICABLE TO VISUAL EMISSIONS

PARTICULATES

State	Fuel Burning[1] Percent Opacity	Industrial Processes Percent Opacity
Florida	20[2]	No visible discharges[3]
Georgia	20[2]	10[4]
Indiana	40	40
Iowa	40	40
Michigan	20[5]	20[5]
New Jersey	20[6]	20
New York	20[7]	20[7]
Oklahoma	20	20
Texas	20[8]	20[8]

Notes for Table II

1. When presence of uncombined water is the only reason for failure of emissions to meet limitation, these requirements do not apply.

2. For new equipment; 40 percent for existing equipment.

3. For sulfuric acid plants and nitric acid plants. Other plants not specified.

4. For new portland cement plants, new nitric acid plants, and new sulfuric acid plants. Other plants not specified.

5. Proposed rule change. Existing regulation calls for 40 percent.

6. Applies to indirect heat exchangers with a rated hourly capacity of 200 mm Btu or greater gross heat input. If input is less than 200 mm Btu, no visible emissions are permitted.

7. May not exceed this value for more than 3 minutes out of any 60 minute time period. May not exceed 40 percent during this 3 minute period.

8. For new installations. Thirty percent for existing installations.

3. EMISSION OF NITROGEN OXIDES AND SULFUR OXIDES FROM FUEL BURNING OPERATIONS

The rate of allowable emission is shown in Table III. However, enforcement of these regulations will undoubtedly be affected by the current uncertainty in regard to the reliability of analyses for nitrogen oxides (see Section VI).

TABLE III

EMISSION OF NITROGEN OXIDES AND SULFUR OXIDES

FROM FUEL BURNING OPERATIONS

	Nitrogen Oxides Lbs/MM Btu Heat Input (As NO_2)			Sulfur Oxides Lbs/MM Btu Heat Input (As SO_2)		
	Liquid Fuel	Solid Fuel	Gaseous Fuel	Liquid Fuel	Solid Fuel	Gaseous Fuel
Florida[1]	0.30	0.70	0.20	0.80	1.20	----
Georgia[2]	0.30	0.70	0.20	0.80	1.20	----
Indiana	0.30[3]	0.70[3]	0.20[3]		See Note 4	
Iowa	0.30[6]	----	0.20[6]	1.5[5]	5.0[5]	----
Michigan		See Note 7			See Note 8	
New Jersey		See Note 9			See Note 10	
New York	0.30[11]	0.70[11]	0.20[11]		See Note 12	
Oklahoma[14]	0.30	0.70	0.20	0.8[13]	2.0	0.20
Texas		See Note 15			See Note 16	

Notes for Table III

1. New sources, maximum 2 hour average. All sources after July 1, 1975.

2. New sources. For existing sources:

$$S = 4000F\left(\frac{h_s}{300}\right)^n$$

Where S = SO_2 emitted, lbs/hr

h_s = Stack height, ft

n = 3 for $h_s < 300$

n = 2 for $h_s \geq 300$

f Varies from 0.8 to 3.0 depending upon heat input and location of source.

3. For fuel burning equipment with a capacity of 250 mm Btu/hr or more.

4. Sulfur dioxide emission for new sources with a heat input of more than 250 mm Btu/hr shall comply with the Federal emission standards. For new sources with a heat input of 250 mm Btu/hr or less, and for existing equipment, the emission rate shall be limited to that expressed by:

$$Em = 17.0\ Q_m^{-0.33}$$

Where Em = Maximum allowable SO_2 in the stack gases in lbs/mm Btu heat input

Q_m = Heat input, mm Btu/hr

5. Maximum 2 hour average after January 1, 1975. From January 1, 1974 to January 1, 1975, the limits are 2.0 for liquid fuels and 6.0 for solid fuels.

6. Maximum 2 hour average, effective January 1, 1974.

7. No limits stated.

8. Limitations apply to steam generating stations only.

9. No limits stated.

10. Very involved method used for determining allowable SO_2 emission. See New Jersey Air Pollution Control Code, Chapter 8, Sections 2.2, 2.3, and 2.17.

11. Applies to installations with a heat input of more than 250 mm Btu/hr.

12. Limitations are placed on sulfur content of fuel rather than on emissions.

13. After July 1, 1975, limit is 0.3 lbs/mm Btu.

14. All figures are based on a maximum 2 hour average.

15. Limitations apply to gas-fired steam generating units only.

16. For fuel burning units other than steam generators, limitations are based on ground level concentration averaged over a 30 minute period. They are:

Galveston and Harris Counties - 0.28 ppm

Jefferson and Orange Counties - 0.32 ppm

Other counties - 0.40 ppm

SECTION IV - CALCINING OF GYPSUM

For the manufacture of gypsum products, the gypsum must be converted from calcium sulfate dihydrate ($CaSO_4 \cdot 2H_2O$) to calcium sulfate hemihydrate ($CaSO_4 \cdot 1/2H_2O$) by calcining under controlled temperature conditions so that calcium sulfate anhydrite ($CaSO_4$) is not produced. Strictly speaking, the term "gypsum" refers only to the dihydrate, but the term is almost universally used in referring to the hemihydrate and anhydrite as well. Block flow diagram No. 3411-A shows the relationship between steps in the process and composition of the gypsum.

Gypsum is mined in both open pit and underground mines. Calcining plants are located near these mines or along a seaboard or major waterway if imported gypsum is used. The run-of-mine gypsum is reduced in size and free water removed before calcining to remove the combined water. Referring to flow diagram No. 3411-B, a brief description of the process is:

Run-of-mine gypsum is conveyed to a crusher feed bin. From this bin it passes over a vibrating screen to a crusher. The underflow from the screen and the discharge from the crusher are combined and conveyed to a crushed rock hopper. A portion of this material may be screened to provide the proper size rock to be sold for use as a portland cement retarder. Rock from the hopper is fed to a surge bin from which it flows (or is conveyed) to a grinding mill. This mill is usually a Raymond type which grinds, classifies, and dries the rock. When calcining or drying gypsum, the mill is in a circuit in which the solid is subjected to hot gases during grinding. In this setup, the mill fan draws hot

combustion gases through a flue from a furnace. From the mill the hot dust-laden gases exit through a duct to a cyclone collector, from which the finished product drops to a bin while any remaining dust is removed by a baghouse collector. The hot combustion gases are exhausted by a fan from the bag collector with part of the gas being recycled to the furnace. This is shown on flow diagram No. 3411-B1. The ground rock from the mill (80 percent $<$100 mesh) is known as "land plaster" and may be sold as such for agricultural purposes. This material is conveyed to the land plaster bins which feed the calciners when further treatment is required.

Calcining is usually done batchwise in vertical kettles until the temperature of the mass reaches a maximum of 320 to 340F. The calcined materials, known as "hot stucco" is then dropped to the hot pits. The stucco is then conveyed to stucco storage bins. Improperly calcined material may be conveyed to the stucco reject bin from where it is recycled back to the crushed rock storage bin. In some plants, continuous calcining is carried out in a Raymond mill. This simultaneously crushes, classifies, removes the surface moisture, and calcines the gypsum.

The finished stucco may be sold as such for use in various plasters, Keene's cement, etc. It is also the major raw material for a board products plant. If such a plant is built in conjunction with a calcining plant, the stucco is conveyed to the feed bins of the board plant.

The only air pollutants from this process are gypsum dust and stack gases from the heaters for the Raymond mills and from the calciners. The fuel used for the heaters and calciners may be gas or oil. If oil is used there may be SO_x and NO_x emissions.

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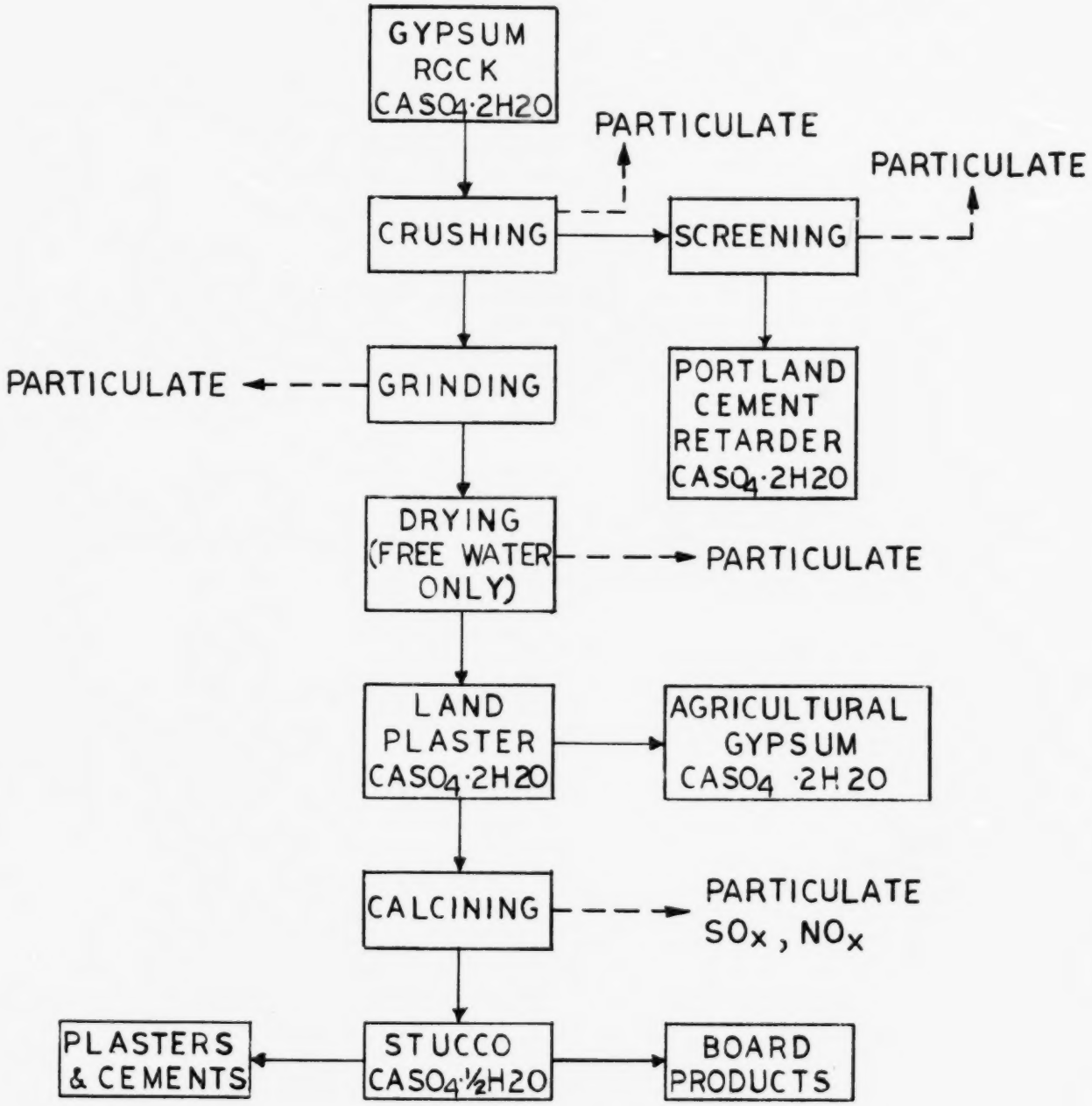
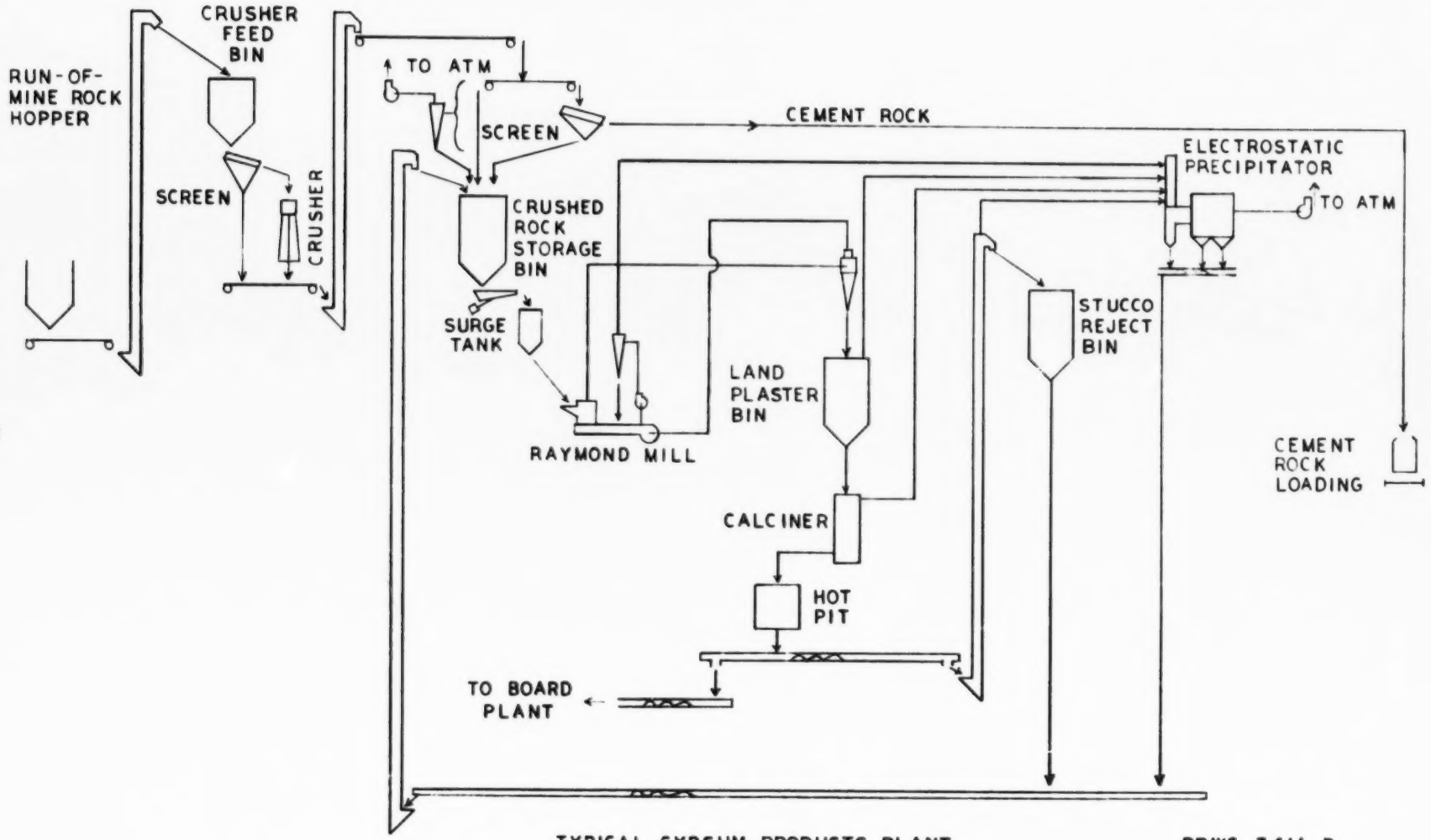
DRWG. 3411-A



PRODUCT BLOCK FLOW DIAGRAM



TYPICAL GYPSUM PRODUCTS PLANT
CRUSHING, MILLING, AND CALCINING

DRWG. 3411-B

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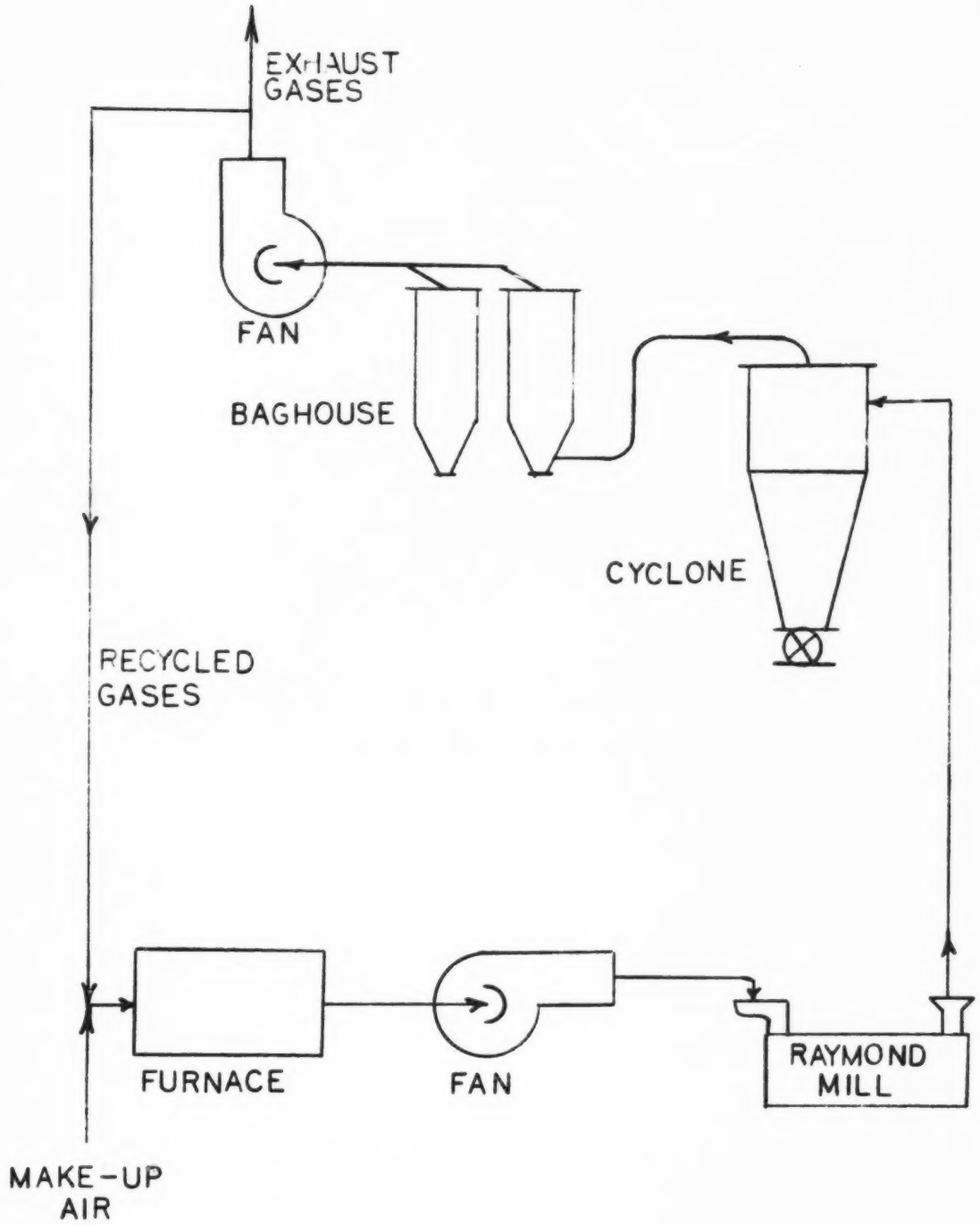

EXHAUST
GASES
FAN
BAGHOUSE
CYCLONE
RECYCLED
GASES
FURNACE
FAN
RAYMOND
MILL
MAKE-UP
AIR

DRWG 3411-B1

The major sources of emission and types of pollutants are:

Source	Pollutant
Primary crusher	Dust
Crushed rock screen	Dust
Crushed rock bin	Dust
Crushed rock feeder	Dust
Grinding mill	
Gas fired	Dust
Oil fired	Dust
	SO_2
	NO_x
Calciners	
Gas fired	Dust
Oil fired	Dust
	SO_2
	NO_x
Land plaster bin	Dust
Stucco reject elevator	Dust

Emissions from the grinding mill, land plaster bin, calciners, and stucco reject elevator may be too hot to be sent to a baghouse and the dust is too fine to be collected efficiently in a cyclone. Therefore, they are usually conveyed to an electrostatic precipitator. If the calciners and grinding mill heaters are oil fired, the exhaust gases from the precipitator may have to be scrubbed to bring the SO_2 down to acceptable levels.

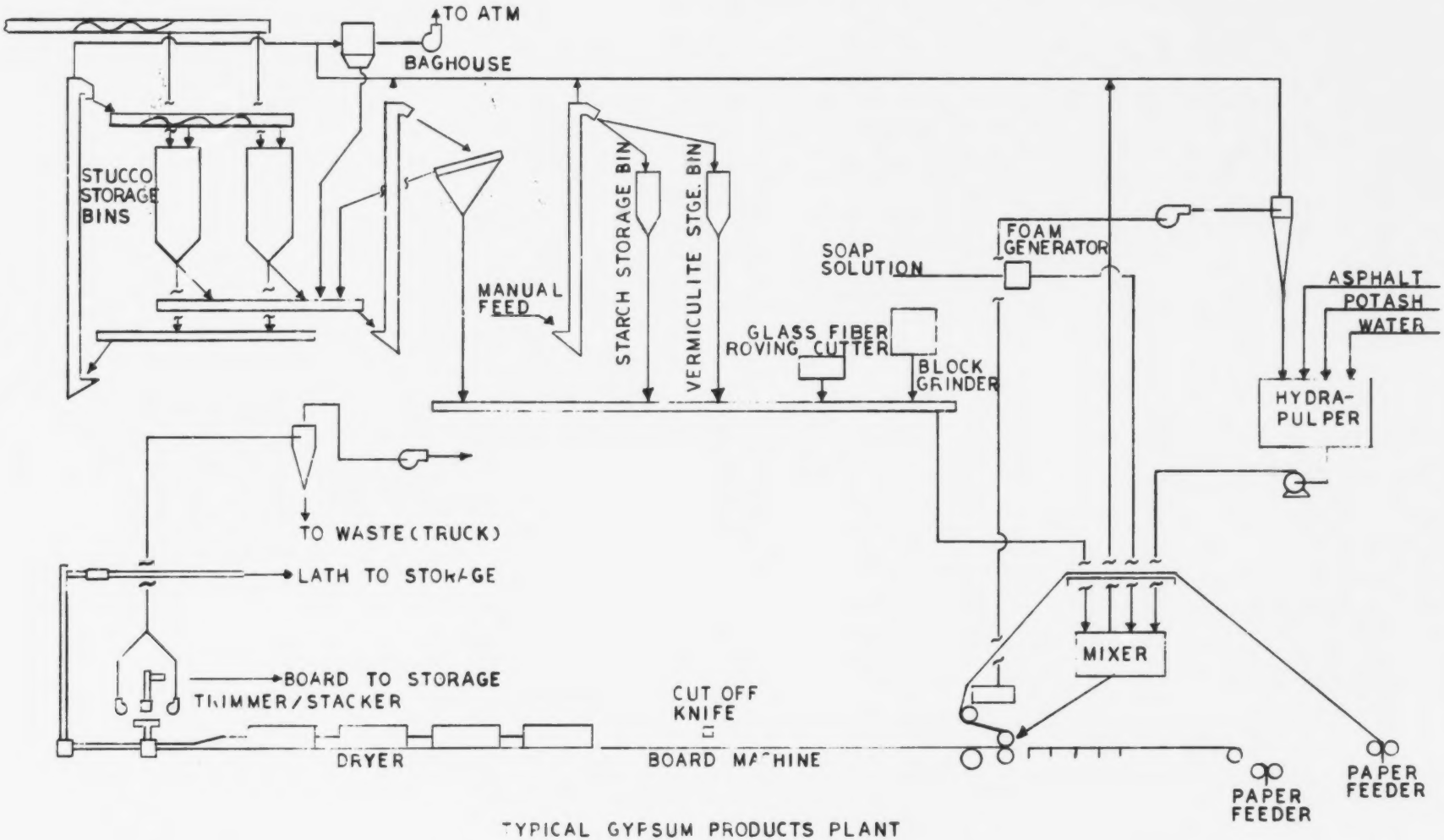
The dust from the primary crushing and screening operations is usually collected in cyclone units. It is usually necessary to supplement these with baghouse units or a precipitator for additional cleanup.

SECTION V - BOARD PRODUCTS

In manufacturing board products from gypsum, water is mixed with the stucco and various materials are added to impart the required properties to the finished product. The nature of these additives will vary, depending upon whether the finished product is wallboard, acoustical board, insulating board, etc. A typical process for making wallboard is shown on flow Diagram 3411-C. Referring to this flow diagram, a brief description of the process is:

Stucco from the hot pits is conveyed to the stucco storage bins in the board plant. No attempt is made to cool this stucco since the elevated temperature will not affect the process adversely. The stucco is conveyed by a screw conveyor to an elevator and discharged to a vibrating screen. Any agglomerates which may have formed are screened out and returned to the screw conveyor where the shearing action of the conveyor will break them up. The underflow from the screen flows to a transfer conveyor. Various additivies such as starch, vermiculite, chopped glass fiber, and ground scrap are also added in this conveyor. This mixture is conveyed to a mixer where foamed soap from a foam generator and a mixture of asphalt, potash, and water from a Hydrapulper are also added. This material is thoroughly mixed to form a thick slurry, or paste, which is fed to the board machine.

In the board machine the paste is fed uniformly onto a liner paper. A top paper liner is applied under a pair of nip rolls and edge folders. This sandwich is then conveyed on a flat belt conveyor until the core hardens - usually about 6 minutes. The board is then cut automatically by a revolving knife.



TYPICAL GYPSUM PRODUCTS PLANT
BOARD AND LATH PRODUCTION

DRWG. 3411-C

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The cut boards are automatically turned over and passed through a long, four-section kiln dryer. The boards leaving the dryer are turned face to face and end sawed to give smooth, straight ends. They are then bundled and stacked in preparation for shipping or warehousing.

With minor modifications in operations, lath and sheathing can be made on the same equipment. The process is the same as described for wallboard.

The only air pollutants from this process are gypsum dust and wallboard dust, which are essentially the same thing. Dusts from the stucco handling system, the additives elevator, and the mixer, go directly to a baghouse. Dust from the board-forming machine goes to a cyclone collector. The solids from this collector flow to the Hydrapulper and the air goes to the baghouse. Solids from the baghouse are recycled to the stucco feed screw.

Dust from the end saws goes to a cyclone or baghouse collector. The collected dust may be recycled as an additive or may be discarded. Air from the collector is discharged to the atmosphere.

SECTION VI - EMISSIONS, ANALYSIS AND CONTROL

A. ANALYSIS

The determination of the quantity of emissions from a gypsum products plant is facilitated by the fact that most emissions are carried in airstreams which are moved by blowers. Few natural draft stacks are involved. These blowers are usually used as exhausters on the downstream side of dust collection equipment.

The most accurate method in general use to determine the quantity of air moved by a blower is a duct traverse using a standard pitot tube (Ref. 3b). Frequently it is possible to make a close approximation of the flow rate by measuring the operating horsepower of the blower and the differential head across the blower. The flow rate can be found from the performance curve. The accuracy will depend on the characteristic curve for the blower.

The determination of the quantity of particulate matter carried in any stream is best made by passing a known quantity of the stream through a flash-fired glass fiber filter which is weighed before and after the sample is taken (Ref. 3b). The highest temperature of any of these streams from a gypsum plant is below the temperature limit of the filters and filter holders available. In making these determinations, it is important that isokinetic sampling techniques are used.

Since the only SO_2 which will be emitted from a gypsum plant will be from a combustion process using oil, the simplest way to determine it is to analyze the oil for sulfur content. All of this sulfur will be converted to SO_2 so the total emission of SO_2 will depend on the firing rate.

The problem of measuring nitrogen oxides, especially in the presence of sulfur oxides, is being extensively studied by many organizations. None of the methods now available give completely satisfactory results (Ref. 3b, 4 and 5). However, some of the newer methods seem promising. One of these is the electrochemical sensor equipped to determine both SO_2 and NO_x. In this unit, the SO_2 is not differentiated by the NO_x sensor but the NO_x does not interfere with the SO_2 sensor. Both sensors are used and the NO_x measurement is corrected to allow for the SO_2 level. In using this method the sample must be filtered and cooled. This could be done in conjunction with the test for particulate matter.

In a properly fired unit, carbon monoxide should not be present in the outlet gases. It is the only one of the fixed gases which is a pollutant. The classical procedure for measuring it is to pass the gas sample over hot iodine pentoxide and titrate the iodine liberated. Carbon monoxide is also measured by gas chromatography and by nondispersive infrared (NDIR) analyzers. The NDIR analyzers have rapid response and good sensitivity but tend to drift so that fairly frequent zeroing and calibration may be necessary. All of these methods require that the sample be filtered and cooled.

In discussion with gypsum manufacturers in the United States, it has been determined that no fluorine bearing gypsum (byproduct of phosphoric acid manufacture) is used to produce commercial gypsum, wall board, and associated products. Therefore, in regard to the gypsum industry, emissions of fluorines and fluorides are not considered to be a problem.

B. CONTROL

The best way to control SO_2 is to use a low sulfur fuel. If this is not feasible the SO_2 may be removed from the stack gas by wet scrubbing. One system uses a lime slurry which reacts with the SO_2 to form sulfates and sulfites (Ref. 3a). This, of course, precludes recovery of the SO_2. Another systems uses a hot solution of potassium sulfite (K_2SO_3) for scrubbing (Ref. 3a). The sulfite reacts with SO_2 to form potassium bisulfite. Cooling the hot bisulfite solution converts the bisulfite ($KHSO_3$) to the pyrosulfite ($K_2S_2O_5$) which is concentrated and steam stripped to produce SO_2 and potassium sulfite. The latter is reused in the scrubber. This system requires close temperature control and uses about four pounds of steam for each pound of SO_2 recovered.

The reduction of nitrogen oxides to less than 200 ppm in an effluent stream is very difficult. Much of the current technology involves scrubbing with alkaline solutions but this is of limited value because of the low solubility of nitrogen oxides in water (Ref. 3a). This problem is also being extensively investigated by several organizations.

The most efficient equipment for the collection of particulate matter is the electrostatic precipitator. It is also the most expensive and is used in gypsum plants only when the effluent is too hot to be collected in a baghouse. The use of cyclone collectors and baghouses should be satisfactory if proper units are chosen for the various services. Wet collectors are usually avoided since they convert an air pollution problem to a water pollution problem.

Both baghouse collectors and electrostatic precipitators used to collect gypsum dust have collection efficiencies of 95 to 99 percent. The cost information relating to these two types of equipment are presented in the following tables.

TABLE IV

BAGHOUSE COLLECTOR

Rate: 40,000 acfm

Costs:

FOB (including fan, starter, and 40 horsepower motor)	$40,000
Erected	$50,000
Operating per year	$ 3,200
Maintenance per year	$ 8,000
Capital (12.8 percent of erected cost)	$ 6,400
Total annual cost	$17,600

Sources: "Estimating the Cost of Gas Cleaning Plants" Chemical Engineering, December 13, 1971, Pg 86-96.

"A Manual of Electrostatic Precipitator Technology - Part II - Application Areas." NATIC No. PB-196-381

Table V

Electrostatic Precipitator Installations in Gypsum Plants
(Period 1935-1969)

Pptr. Contract Year (s)	Five (5) Year Period Indicated: No. of Install.	No. of Pptrs.	Total Gas Volume (10^3 acfm)	Average Volume/Year During Period (10^3 acfm)	Weighted Design Efficiency on acfm Basis (%)
1935-1939	4	5	100	20	98.5
1940-1944	3	3	56	11.2	98.6
1945-1949	3	3	77.5	15.5	96.5
1950-1954	18	25	545.5	109	97.5
1955-1959	20	21	607.6	121.5	97.7
1960-1964	10	11	351.6	70.3	99.15
1965-1969	1	2	80	16.0	99.0
Grand Totals	59	70	1818.2		

NOTES: The statistics in this table include precipitators on rock dryers, kettles, rotary calciners, holoflite calciners, and combinations of calciners and kettles with dryer and grinding mill vent gases.

Table VI

Summary of Performance Data on Gypsum Plant Electrostatic Precipitators

	Critical Parameter	Kettles		Rock Dryers		Calciner (Rotary)		Calciner (Holoflite)		Combination Kettle, Dryer, Mill	
		Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1.	Gas Volume/Precipitator (acfm in thousands)	13.6	2.9	43.0	10.8	82.5	29.8	16.6	7.6	60.2	9.0
2.	Precipitator Efficiency (per cent)	99.90	94.38	99.85	97.20	99.82	99.14	99.90	98.20	99.96	93.76
3.	Gas Velocity in Precipitator (fps)	5.5	1.5	7.5	3.1	7.9	4.2	2.8	1.4	7.4	3.0
4.	Precipitator Dust Concentration (gr/scfd)	48.0	4.8	156	4.6	46.3	32.9	62.6	30.8	63.9	7.7
5.	Precipitator Input Power (watts/1000 acfm)	828	124	282	69	174	62	983	576	390	65
6.	Precipitator Avg. Field Strength (kV/in.)	12.8	8.8	15.0	9.0	13.0	8.1	15.5	9.8	13.4	8.0
7.	Gas Moisture (per cent by volume)	47.6	19.0	17.4	3.6	35.2	14.2	54.0	17.6	22.2	6.7
8.	Gas Temperature (°F)	342	220	240	125	-	-	339	200	250	140
9.	Precipitator Performance Ratio (R)	2.39	0.74	2.06	0.89	1.45	1.03	1.39	0.47	2.39	0.40

Economics. Table VII shows erected and FOB costs for precipitators installed in gypsum plants over the period 1959-1967. The costs per acfm range from $0.89 to $1.03 for 99.0% collection efficiency, and from $1.43 to $1.53 for 99.5%. Erected costs vary from $1.38 to $3.62 per acfm.

Table VIII lists the maintenance costs for two precipitators installed in gypsum plants. The fan costs were based on a pressure drop of 1/2" W.G. in the precipitator. The plant was assumed to operate 8000 hours per year with electricity costs estimated at $0.0075 per kWh.

Table VII

Gypsum Industry Economics

Year	Type Cost	Design Volume (1000's acfm)	Design Efficiency (%)	Total Cost (10^3 $)	Cost/Unit Volume ($/acfm)
1959	FOB	40	99.0	39.5	0.99
	Erected	40	99.0	55.2	1.38
1960	FOB	40	99.0	38.7	0.97
1961	Erected	40	99.7	90.1	2.25
1962	FOB	40	99.0	35.7	0.89
1964	FOB	36	99.5	55.0	1.53
		36	99.5	51.3	1.43
		36	99.5	56.3	1.57
		40	99.0	36.0	0.90
1965	Erected	27	99.0	97.8	3.62
1967	FOB	40	99.0	41.0	1.03

Table VIII

Maintenance Data for Precipitators Installed on Gypsum Calciners

Prod. Rate tons/hr.	17-17	60-90
Gas Flow, acfm	16,600	35,000
Precipitator Power, kW	12.2	13.5
No. of Maintenance Periods/year	3-4	3-4
Man hours/year	70-90	70-90
Maintenance Labor Costs[1]	480	480
Fan Power, kW[2]	1.04	2.19
Power Costs - Fan[3], $/yr.	62.25	131.25
Power Costs - Precipitator, $/yr.	730	810
Capital Costs,[4] $/yr.	8,600	9,350
Total Annual Costs	9,872.25	10,771.25

[1] Based on $6.00 per hour
[2] Based on 1/2" W.G. pressure drop
[3] Based on Power Costs at $0.0075 per kWh
[4] Based on 12.8% of total Erected Costs

SECTION VII - LIST OF PRODUCERS

Gypsum and/or gypsum products are produced in twenty-eight of the conterminous states at 79 locations. Six major producers account for sixty-nine, or 87-1/2 percent, of these installations. There is no breakdown available showing the nominal capacity or production for any of these producers. However, the latest data (1971) available for the overall industry shows this breakdown (Ref. 6):

Product	Capacity Short Tons	
Uncalcined		
Portland cement retarder	3,349,018	
Agricultural gypsum	849,970	
Fillers and unclassified	106,003	
Total		4,304,991
Calcined Plasters		
Building Plasters		
Regular basecoat	381,471	
Mill-mixed basecoat	188,556	
Veneer plaster	89,723	
Gouging, molding, and Keene's cement	75,251	
Roof-deck concrete	180,803	
Total		915,804
Industrial Plasters		268,212
Board Products	MSF	
Lath	477,403	
Veneer base	292,257	
Gypsum sheathing	272,269	
Regular gypsum board	9,014,908	
Type X gypsum board	1,766,483	
Predecorated wallboard	122,361	
Total (MSF)		11,945,681

If all of the board products averaged out at 1/2 inch thickness, which gives a weight of 2 pounds per square foot, the tonnage of board products is the same as the thousands of square feet produced. Using this assumption, the total tonnage of gypsum and gypsum products produced in 1971 is 17,434,688 short tons. This is in close agreement with the apparent supply of crude gypsum which was estimated at 16,688,235 short tons (including imports) in 1971 (Ref. 6).

The seven major producers and the location of their installations are:

Company	State	City
The Celotex Corporation	Iowa	Fort Dodge
	New Jersey	Edgewater
	Ohio	Port Clinton
	Texas	Hamlin
	Wyoming	Cody
The Flintkote Company	California	Fremont
	Georgia	Savannah
	Nevada	Las Vegas
	New Jersey	Camden
	Texas	Sweetwater
Georgia-Pacific Corporation Gypsum Division	Delaware	Wilmington
	Georgia	Brunswick
	Iowa	Fort Dodge
	Kansas	Blue Rapids
	Michigan	Grand Rapids
	New York	Akron
		Buchanan
	Texas	Quanah
	Utah	Sigurd
	Wyoming	Lovell
Johns-Manville Corporation	Nevada	Las Vegas
	Arizona	Florence
Kaiser Cement and Gypsum Corp.	California	Antioch
		Long Beach
	Florida	Jacksonville
	New Jersey	Delanco
	Washington	Seattle

Company	State	City
National Gypsum Company	Arizona	Phoenix
	California	Long Beach
		Richmond
	Connecticut	New Haven
	Florida	Tampa
	Georgia	Garden City
	Illinois	Waukegan
	Indiana	Shoals
	Iowa	Fort Dodge
	Kansas	Medicine Lodge
	Louisiana	Westwego
	Maryland	Baltimore
	Michigan	National City
	New Hampshire	Portsmouth
	New Jersey	Burlington
	New York	Bronx
		Clarence Center
	Ohio	Lorain
	Texas	Rotan
United States Gypsum Company	California	Plaster City
		Santa Fe Springs
	Florida	Jacksonville
	Indiana	East Chicago
		Shoals
	Iowa	Fort Dodge
		Sperry
	Louisiana	New Orleans
	Maryland	Baltimore
	Massachusetts	Boston
	Michigan	Alabaster
		River Rouge
	Montana	Lewistown
	Nevada	Empire
	New York	New Brighton (S.I.)
		Oakfield
		Stony Point
	Ohio	Gypsum
	Oklahoma	Southard
	Pennsylvania	Philadelphia
	Texas	Galena Park
		Sweetwater
	Utah	Sigurd
	Virginia	Norfolk
		Saltville

Of the 81 installations, 46 (or 56.8 percent) are located in, or very close to, standard metropolitan statistical areas. These include:

East Coast	21
Gulf Coast	4
West Coast	7
Fort Dodge, Iowa	4
East Chicago, Indiana	1
Buffalo, New York	3
Sandusky, Ohio	2
Sweetwater, Texas	4
	46

SECTION VIII - DATA FROM OPERATING PLANTS

The data shown in Tables IX and X were obtained from the plants indicated.

TABLE IX

EMISSIONS FROM CALCINING OPERATIONS

PLANT DATA

Company and Location	Date Constructed	Dust Emission, Lbs/Hr	Dust Collection Equip.			Fuel Burning		
		Total	Cyclones	Baghouse	Precip.	SO_2 Emission Lbs/Hr	NO_x Emission Lbs/Hr	Fuel Used
Celotex Corp.								
Cody, Wyoming	1962	40			x	Note 1		Note 1
Edgewater, New Jersey	1958	40			x	Note 1		Note 1
Fort Dodge, Iowa	1958	40			x	Note 1		Note 1
Hamlin, Texas	ca. 1945	400	x			Note 1		Note 1
Port Clinton, Ohio	ca. 1945	35			x	Note 1		Note 1
The Flintkote Co.		.02 Grains						
Fremont, California	1965	Per scf			x	Negl.		
Savannah, Georgia	1964	0.5		x	x	Negl.	Negl.	Gas[2]
Georgia-Pacific Corp.								
Buchanan, New York	1969	0.84			x	Negl.	Negl.	Gas
Lovell, Wyoming	1967	0.56			x	Negl.	Negl.	Gas
Grand Rapids Gypsum Co.								
Grand Rapids, Michigan	1970[7]	35			x	Negl.	Negl.	Gas
Johns-Manville Corp.								
Florence, Arizona	1955	0.2		x		Negl.	Negl.	Gas
Las Vegas, Nevada	1965	4.3		x[3]		Negl.	Negl.	Gas
Kaiser Gypsum Co.								
Jacksonville, Florida	1964	45.5		x[3]	x	1.33	Note 4	
Delanco, New Jersey	1966	45				Note 5	Note 4	
National Gypsum Co.								
Richmond, California	1964	0.45		x		0	Negl.	
Fort Dodge, Iowa	1940	7.6	x		x	0	Negl.	
Clarence Center, New York	1940	12.6	x		x	(61)[6]	Negl.	
Long Beach, California	1965	0.9		x		0	Negl.	
United States Gypsum Co.								
Shoals, Indiana	1955	5307	x			Negl.	Negl.	
Stony Point, New York	1956	96			x	Negl.	Negl.	
Baltimore, Maryland	1962	5.11		x		Negl.	Negl.	

Notes for Table IX

1. SO_2 from low sulfur fuel meets Federal standards.
2. No. 2 fule oil standby.
3. Also use a wet scrubber.
4. Unknown.
5. Unknown. Low sulfur fuel is used.
6. Quantity reported as 250 tons per year. Quantity shown is calculated using 8160 operating hours per year.
7. Board plant built in 1920.

TABLE X

EMISSIONS FROM BOARD PLANT OPERATIONS

Company and Location	Dust Emission, Lbs/Hr: Paper Dust	End Trim Dust	Board Drying	Total	Dust Collection Equip.: Cyclones	Baghouse	Precip.	Fuel Burning: SO_2 Emission Lbs/Hr	NO_x Emission Lbs/Hr	Fuel Used
Celotex Corp.										
Cody, Wyoming				30	x			Negl.	Negl.	Gas
Edgewater, New Jersey				5		x		Negl.	Negl.	Gas
Fort Dodge, Iowa				5		x		Negl.	Negl.	Gas
Hamlin, Texas				30	x			Negl.	Negl.	Gas
Port Clinton, Ohio				Note 1		Note 2		Negl.	Negl.	Gas
The Flintkote Co.										
Freemont, California				Note 3		x		Negl.	Negl.	
Savannah, Georgia				0.5		x		Negl.	Negl.	Gas[4]
Georgia-Pacific Corp.										
Buchanan, New York	.01	.18		.19		x		Negl.	Negl.	Gas[4]
Lovell, Wyoming	.01	.18		.19		x		Negl.	Negl.	Gas
Grand Rapids Gypsum Co.										
Grand Rapids, Michigan				5		x[5]		Negl.	Negl.	Gas
Kaiser Gypsum Co.										
Jacksonville, Florida				33.3		x		12.5	Note 6	
Delanco, New Jersey				14		x		Negl.	Negl.	Gas
National Gypsum Co.										
Richmond, California				2.8	x	x		Negl.	Negl.	Gas
Fort Dodge, Iowa				2.6	x	x		Negl.	Negl.	Gas
Clarence Center, New York				2.1	x	x		(94.4)[7]	Negl.	
Long Beach, California				2.9	x	x		Negl.	Negl.	
United States Gypsum Co.										
Shoals, Indiana	15.4	3.6		19	x	x		Negl.	Negl.	Gas[4]
Stony Point, New York				12.8	x	x		Negl.	Negl.	Gas[4]
Baltimore, Maryland				9.9	x	x		Negl.	Negl.	

Notes for Table X

1. None reported.
2. Closed system.
3. 99 percent of particles greater than 0.5 microns collected.
4. No. 2 fuel oil standby.
5. Also use a wet scrubber.
6. Quantity of NO_x emission unknown.
7. Quantity reported as 340 tons per year. Quantity shown is calculated using 7200 operating hours per year.

A rough estimate of nationwide particulate contamination from gypsum product plants can be made by using an average dust emission figure. From the data available this is 340 lbs/hr for crushing, grinding, and calcining operations, and 10.3 lbs/hr for board plants. An average board line will produce 400 square feet per minute, or

$$\frac{400\ (1440)\ 365}{1000} = 210{,}240 \text{ MSF per year.}$$

Since approximately 12,000,000 MSF per year are produced (see Section VII), the total emission for board lines is

$$\frac{12{,}000{,}000}{210{,}240}(10.3) = 588 \text{ lbs per hour nationwide.}$$

The total quantity of gypsum processed is approximately 17,500,000 tons per year. The average plant will process about 1000 tons of rock per day. Therefore, the approximate total emission for rock processing, is

$$\frac{17{,}500{,}000}{365\ (1000)}\ (340) = 16{,}300 \text{ lbs per hour nationwide}$$

This is based on continuous three-shift operation.

If the mill is operated on a one-shift basis, the dust emission rate would be three times this. Thus, the total dust emission rate could be as high as 49,500 pounds per hour on a nationwide basis.

SECTION IX - BEST CONTROLLED PLANTS

The best controlled plants are the latest ones built, and are equipped with baghouses or electrostatic precipitators or a combination of the two. Among these are:

The Celotex Corporation	Cody, Wyoming
The Flintkote Co.	Savannagh, Georgia
Georgia-Pacific Corporation	Buchanan, New York
Grand Rapids Gypsum Co.	Grand Rapids, Michigan
Johns-Manville Corporation	Florence, Arizona
	Las Vegas, Nevada
Kaiser Gypsum Co.	Delanco, New Jersey
National Gypsum Co.	Long Beach, California
United States Gypsum Co.	Baltimore, Maryland

The quantity of emissions for these plants and the type of control equipment in use is shown in Tables IX and X.

A baghouse collector costs approximately five times as much as a comparable cyclone collector. An electrostatic precipitator can be installed at a cost comparable to a baghouse if the flow quantity is high. The minimum flow rate for an industrial type precipitator is approximately 50,000 absolute cubic feet per minute.

SECTION X - FORECAST OF GROWTH

The demand for gypsum products is directly related to the housing industry. For the past five years the domestic production of crude gypsum has leveled off at 10 to 10.5 million short tons per year, with the balance of the crude supplied as imports. Conceivably, this situation could continue for the next few years and present gypsum producers attach a low probability to the possibility of new gypsum plants in the short term.

Current indications of a rising trend in the housing industry could, however, lead to expansion of existing plants or possibly to new gypsum board plants in the near future.

SECTION XI - INFORMATION SOURCES

A. COMPANIES AND ORGANIZATIONS CONTACTED

Celotex Corp. 1500 N. Dale Mabry Tampa, Florida 33607 (813) 872-3111	Marion M. Hambrick Vice President of Operations
Flintkote Co. 400 Westchester Ave. White Plains, New York 10604 (914) 761-7400	J. E. Krebs Project Engineer
Georgia-Pacific Corp. 900 S. W. Fifth Street Portland, Oregon 97207 (503) 222-5561	Vincent J. Tretter, Jr. Senior Environmental Engineer
Johns-Manville Corp. Greenwood Plaza Denver, Colorado (303) 770-1000	Edmund M. Fenner Director of Technical Relations
Kaiser Gypsum Co. 300 Lakeside Drive Oakland, California 94612 (415) 271-2211	Robert Costa Vice President and General Manager
National Gypsum Co. 325 Delaware Avenue Buffalo, New York 14202 (716) 852-5880	W. A. Schmidt Chief Dust Control Engineer
United States Gypsum Co. 101 South Wacker Drive Chicago, Illinois 60606 (312) 321-3400	John F. Schroder Manager of Environmental Protection
The Gypsum Association 201 N. Wells Street Chicago, Illinois 60606 (312) 726-5675	F. J. Rogers Manager, Administrative Services
Grand Rapids Gypsum Co. 1007 N. Division Ave. Grand Rapids, Michigan 49501 (616) 459-6183	Not contacted. Data obtained through the Gypsum Association

B. EQUIPMENT COMPANIES

The Coe Manufacturing Co.
Painesville, Ohio 44077

The Ehrsam Co.
300 N. Cedar
Abilene, Kansas 67410

Combustion Engineering Co.
Raymond Division
427 W. Randolph St.
Chicago, Illinois 60606

C. STATES (Air Pollution Regulations)

California

California Air Resources Board
1108 14th Street
Sacramento, California 95814

Florida

Department of Pollution Control
Suite 300, Tallahassee Bank Building
315 South Calhoun St.
Tallahassee, Florida 32301

Georgia

Georgia Department of Public Health
47 Trinity Avenue S.W.
Atlanta, Georgia 30334

Indiana

Air Pollution Control Board
1330 West Michigan St.
Indianapolis, Indiana 46206
ATT: Mr. Perry E. Miller
Technical Secretary

Iowa

Iowa Air Pollution Control Commission
Iowa State Department of Health
Lucas State Office Building
Des Moines, Iowa 50319
ATT: Mr. Charles Campbell

Michigan

Bureau of Industrial Health and Air Pollution Control
Department of Public Health
3500 N. Logan
Lansing, Michigan 48914

New Jersey

New Jersey State Department of Environmental Protection
Bureau of Air Pollution Control
P. O. Box 1390
Trenton, New Jersey 08625

New York

New York State Department of Environmental Conservation
41 State Street
Albany, New York 12207

Oklahoma

Environmental Health Services
Air Pollution Control Division
Oklahoma State Department of Health
3400 N. Eastern
Oklahoma City, Oklahoma 73105

Oregon

Department of Environmental Quality
1400 Southwest Fifth Avenue
Portland, Oregon 97201
ATT: Mr. H. M. Patterson
Chief, Air Quality Control

Texas

Texas Air Control Board
1100 West 49th Street
Austin, Texas 78756

D. PUBLICATIONS

1. American Petroleum Institute Engineering Reports
   Cyclone Dust Collectors, 1955
   Removal of Particulate Matter from Gaseous Wastes - Filtration, 1961
   Electrostatic Precipitators, 1961

2. Chemical Economics Handbook - Standford Research Institute, July 1971

3. Chemical Engineering Deskbook

   a. Environmental Engineering, June 1971
   b. Environmental Engineering, May 1972

4. Combustion, August 1972

5. Environmental Science and Technology, October 1972

6. Mineral Industry Surveys - Gypsum (Quarterly)
   U. S. Bureau of Mines, 1971

7. Minerals Yearbook - U. S. Bureau of Mines, 1970

8. Pit and Quarry, August 1961

9. Pit and Quarry Handbook, 1971-72

10. Rock Products, November 1960

11. Rock Products, June 1966

E. PLANT VISITS

National Gypsum Co., Shoals, Indiana	December 4, 1972
United States Gypsum Co., Shoals, Indiana	December 4, 1972
Georgia-Pacific Corp., Buchanan, New York	December 6, 1972
United States Gypsum Co., Stony Point, New York	December 6, 1972

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RATA

Changes
to
Final Report

Screening Study For Background Information
and
Significant Emissions
from
Gypsum Product Manufacturing

Page	Paragraph	Line	
iii	1	3	"...between 25 and 40 pounds..." should be: "...between 25 and 100 pounds...".
1	3	1	" The scope of this preliminary report deals with the two major industry operations: A. Calcining of gypsum B. Production of board products" should be: "The scope of this preliminary report deals with the following major industry operations: A. Drying of gypsum B. Grinding of gypsum C. Calcining of gypsum D. Production of board products E. Miscellaneous manufacturing".
2	1	4	"...25 to 40 pounds" should be: "...25 to 100 pounds..."
2	1	5	add to the end of sentence" when a proper interpretation of source operations is used".
3	5	3	add sentence "...operation. Source operations should include at least the following major processes: "A - Drying B - Grinding C - Calcining D - Production of Board Products E - Misc. Manufacturing Operations" Remainder of paragraph should be a new paragraph.
14	2	2	"...reaches a maximum of 320 to 340F." should be: "...reaches a maximum of 295 to 340F."
15	-	-	Replace with attached Product Block Flow Diagram
16	-	-	Replace with attached Typical Gypsum Products Plant
18	1	4-5	Rock Dryer should be added between "Crushed rock feeder" and "Grinding mill" under source column and "Dust" should be added under "Pollutant" for this entry.

Page	Paragraph	Line	
18	2	5-6	"...may have to be scrubbed to bring..." should be: "...may have to be scrubbed, or low sulfur fuel used, to bring..."
19	1	3-4	" The nature of these..." Delete sentence and add: " The nature of these additives will vary, depending on the finished product."
19	2	4-6	Should be: Any agglomerates which may have formed are screened out. Delete remainder of sentence.
19	3	1	" In the board machine the paste is fed..." should be: " In the board machine the slurry is fed..."
24	1	10	Add the following sentence to the end of the first paragraph: " Much of this technology is still being developed."
24	3	1	" The most efficient equipment for the..." should be: " One of the most efficient pieces of equipment for the..."
24	3	2	" It is also the most expensive..." delete this sentence.
31	1	1-2	"...in twenty-eight of the coterminous states at 79 locations." should be: " in twenty nine of the coterminous states at 80 locations."
32	2	23	The Johns-Manville Corporation Florence plant is in Colorado not Arizona
33	2	12	The United States Gypsum Company River Rouge, Michigan plant should have "(Detroit)" following the River Rouge name.
34	1	1	" Of the 81 installations, 46 (or 56.8 percent)..." should be: "Of the 80 installations, 46 (or 57.5 percent)..."
36	Table IX		SO_2 data for Kaiser Gypsum Company Jacksonville, Florida should be 13.3 instead of 1.33 . The Johns-Manville Corp. Florence plant is in Colorado, not Arizona. Dust emission for U.S. Gypsum Baltimore, Maryland should be 5.11 lb/hr minimum to 72 lb/hr maximum (established from typical data)

Page	Paragraph	Line	
37	-	10	Add note 8 : Values in this table are based on original design efficiencies and may not be representative of actual daily operations.
38	Table X		The dust emission figure shown for Kaiser Gypsum, Delanco, New Jersey should be : 0.6 lb. per hour, not 14 . The United States Gypsum Co., Shoals, Indiana entry for Paper Dust should be 7.7, not 15.4 which changes the total to 11.3, not 19 .
40	2	2	"...plant will process about 1000 tons..." should be: "...plant will process about 850 to 1000 tons..."
41	1	8	Johns-Manville Corp. Florence plant is in Colorado not Arizona.
47	Blk 16	3	"are 25-40 pounds per" should be: "are 25-100 pounds per".

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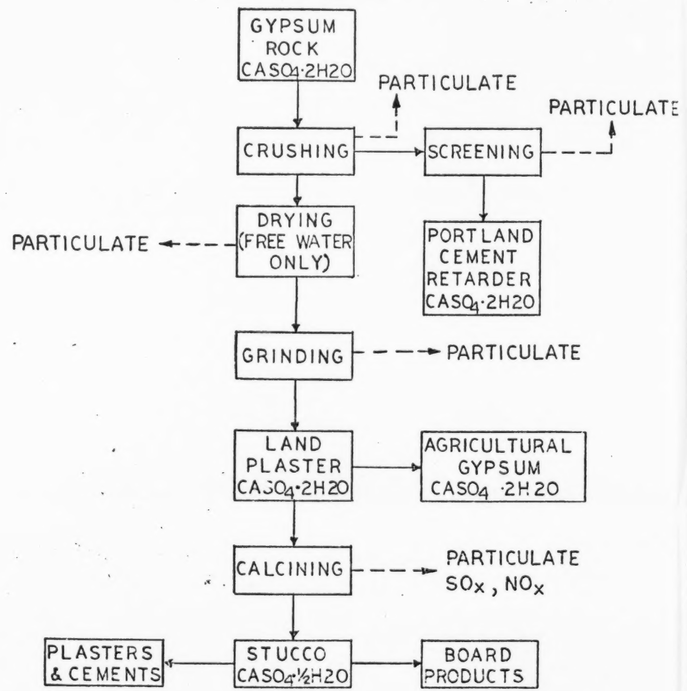
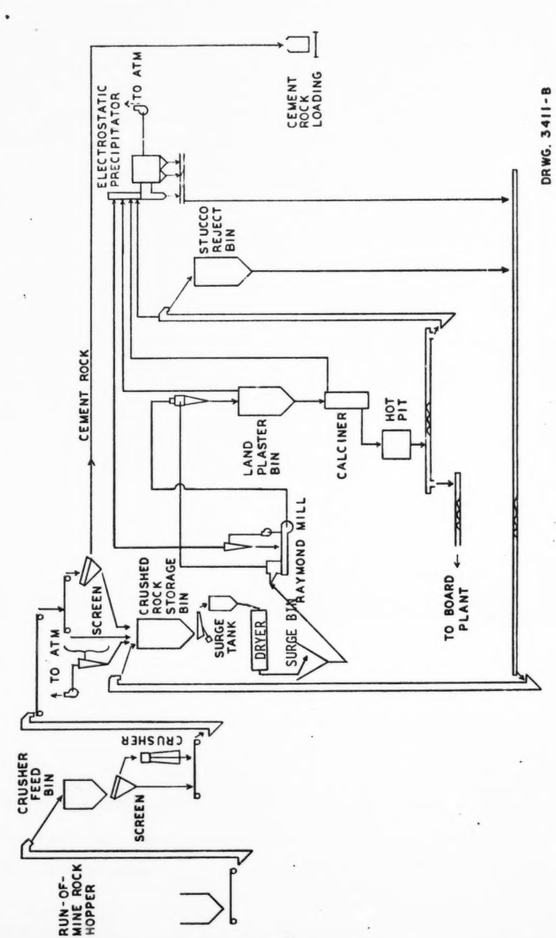
DRWG. 3411-A



PRODUCT BLOCK FLOW DIAGRAM

15



DRWG. 3411-B

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TYPICAL GYPSUM PRODUCTS PLANT
CRUSHING, DRYING, MILLING AND CALCINING

16

ME
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